RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**347-8435**
SRP Section:	**15.04.03 – Control Rod Misoperation (System Malfunction or Operator Error)**
Application Section:	**15.04.03**
Date of RAI Issue:	**12/22/2015**

Question No. 15.04.03-1

REQUIREMENTS AND GUIDANCE

In 10 CFR Part 50 Appendix A, General Design Criterion (GDC) 10 requires the core and associated coolant, control, and protection systems to be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects or anticipated operational occurrences (AOOs). GDC 20 requires, in part, that the protection system be designed to initiate automatically the operation of appropriate systems to ensure that SAFDLs are not exceeded as a result of AOOs. GDC 25 requires the protection system to be designed to ensure that SAFDLs are not exceeded for any single malfunction of the reactivity control systems.

Section 15.4.3 of NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” Subsection III, “Review Procedures,” states the following under Item 1: “*For each failure event analyzed, the cases which result in a limiting fuel rod condition should be presented. Initial conditions and parameter values selected for these cases should be justified with a sensitivity analysis or discussion. Conditions of first-order importance for any time in cycle are initial power level and distribution, initial rod configuration, reactivity addition rate, moderator temperature, fuel temperature, and void reactivity coefficients.”*

ISSUE

The applicant presents a four-finger single control element assembly (CEA) drop as the limiting event analyzed in DCD Section 15.4.3. As analyzed, this event does not cause a reactor trip but results in an approach to the specified acceptable fuel design limit (SAFDL) on minimum departure from nucleate boiling ratio (DNBR). DCD Section 4.3.2.5 indicates that the full-strength CEA drop incident is analyzed by selecting the dropped CEA that maximizes the increase in the radial peaking factor and that a conservatively small negative reactivity insertion is used in the event analysis. However the application does not provide supporting information such as an examination of the range of CEA worths and locations. It is therefore not clear that a CEA drop into both a high flux and low flux region has been considered or that cases with a part-strength CEA drop have been examined.

Furthermore, the maximum radial peak distortion following a four-finger CEA drop is assumed to be 1.205. However, the application does not describe the basis for this factor and the uncertainties that are covered by it. According to the audited calculation note related to this event, APR1400-F-A-TM-12004-P, Rev. 0, “CEA Drop Analysis for US-APR1400,” dated August 2012, the distortion factor of 1.205 is a multiplier on the initial integrated radial peaking factor. DCD Table 15.4.3-2 lists the integrated radial peaking factor as 1.37. According to DCD Table 4.3-10, this roughly corresponds to a “P” (part-strength) rodded core configuration at end-of-cycle (EOC) conditions. Consequently, the integrated radial peaking factor following the CEA drop is 1.205*1.37, which is 1.644. However, absent necessary supporting information, the staff can neither confirm which rodded configuration yields the largest peaking factor nor assess the basis for the assumed maximum radial peak distortion factor of 1.205.

In addition, the audited calculation note indicates that, as of August 2012, the 12-finger CEA drop had not been evaluated but will be in future analyses for the core operating limiting supervisory system (COLSS) and the core protection calculator system (CPCS). The calculation note also states that, if a 12-finger CEA drops, the CPCS will appropriately generate a trip if it is necessary because the CPCS conservatively calculates DNBR every 0.05 seconds. The applicant has nevertheless provided no information on its analyses for 12-finger CEA drop events. Absent such information, the staff can neither assess the applicant’s analyses for a range of 12-finger CEA drop events nor verify their implications, if any, for determining the limiting CEA drop event.

INFORMATION NEEDED

Please provide justification that the four-finger single CEA drop is the limiting event for DCD Section 15.4.3. A summary of analysis results using different rodded core configurations, dropped rod types and locations, and different cycle conditions would assist the reviewer in confirming that the event analyzed is the limiting event. Supporting information should include the basis for the maximum radial peak distortion factor of 1.205 as well as a summary of analyses performed for 12-finger CEA drop events.

As appropriate, the applicant should update the DCD and referenced technical reports.

Response

To calculate the most conservative radial peaking factor for the CEA drop analysis, all possible single CEA drop simulations for all combinations of initial CEA configurations (permitted by the Power Dependent Insertion Limit) at different cycle conditions (including BOC, IOC, MOC, and EOC) were performed. In the calculations, the maximum four-finger CEA drop distortion factor which is 1.2047 was selected as the maximum ratio of post to pre event radial peaking factor as described in Table 1. This factor includes not only [ ]TS that is caused by the dropped CEA but also the [ ]TS for operator action time that can be credited for 30 minutes after the drop. The initial rod configurations and dropped CEA information are also described in Table 1. The location of the dropped CEA that yields the largest peaking factor is full core box number [ ]TS, and the maximum case occurs for the [ ]TS inserted CEA configuration. The location of the CEA can be found in DCD Figure 4.3-36.

When the 12-finger CEA drops into the core, the Control Element Assembly Calculator (CEAC) will generate an artificially large penalty for the DNBR calculation or the LPD calculation due to CEA deviation. This penalty will be transmitted to each CPC and the CPCs will calculate the reactor conditions with this penalty to determine the necessity for a reactor trip. The resultant reactor trip guarantees that the minimum DNBR is greater than the DNBR SAFDL for 12-finger CEA drop events. The paragraph of the audited calculation note indicates that the 12-finger CEA drop had not been evaluated, but will be in future analyses for the core operating limiting supervisory system (COLSS) and the core protection calculator system (CPCS) means that a calculation using the CPC addressable constants for 12-finger CEA drops events will be performed in the detailed design stage.

Table 1 Calculation Cases and Cycle Maximum Peaking Factors of 4-Finger CEA Drop

[ ]TS

Impact on DCD

There is no impact on DCD.

Impact on PRA

There is no impact on PRA.

Impact on Technical Specifications

There is no impact on Technical Specifications.

Impact on Technical/Topical/Environmental Report

There is no impact on any Technical, Topical, or Environmental Report.

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Question No. 15.04.03-2

REQUIREMENTS AND GUIDANCE

In 10 CFR Part 50 Appendix A, General Design Criterion (GDC) 10 requires the core and associated coolant, control, and protection systems to be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects or anticipated operational occurrences (AOOs). GDC 20 requires, in part, that the protection system be designed to initiate automatically the operation of appropriate systems to ensure that SAFDLs are not exceeded as a result of AOOs. GDC 25 requires the protection system to be designed to ensure that SAFDLs are not exceeded for any single malfunction of the reactivity control systems.

Section 15.4.3 of NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” Subsection III, “Review Procedures,” states the following under Item 2: “*For each event, the analytical methods used by the applicant are reviewed… In either case, the reviewer should determine whether the applicant's evaluation methods are acceptable.”*

ISSUE

CEA drop events are analyzed by the applicant with the CESEC-III code described in DCD Section 15.0.2.2.1. The CESEC-III model includes a 3D reactivity feedback model, which is important for incorporating local changes in the thermal-hydraulic conditions. However, a point kinetics solver is used to determine the neutronic behavior in the core. Since the single CEA drop produces an asymmetric flux shape, the point kinetics solution will not yield accurate flux shape information for determining the local peaking factor. The applicant has not addressed how these spatial core physics phenomena are treated in the analysis. This is important because the calculated minimum departure from nucleate boiling ration (DNBR) is near the limit of 1.29. In addition, xenon redistribution following the CEA drop increases the power distortion over time, as indicated in the audited calculation note related to this event (APR1400-F-A-TM-12004-P, Rev. 0, "CEA Drop Analysis for US-APR1400," August 2012). How this is accounted for in the methodology is not clear because CESEC-III does not model 3D xenon distributions.

DCD Section 15.0.2.2.1 indicates that a detailed thermal-hydraulic model simulates the mixing in the lower plenum from asymmetric transients. This, in combination with the use of the CETOP code for computing three-dimensional fluid conditions in the core, should give a reasonable estimate of the local flow conditions and thus the thermal margin on DNBR. However, since mixing in the lower plenum will have an impact on local core physics parameters, more detail is needed for the conditions in the lower plenum. Since the CEA drop is an asymmetric event, using point kinetics may not yield sufficient accuracy in the local peaking factor used to determine the local heat flux, and subsequently, the minimum DNBR. In addition, effects of flow mixing in the lower plenum and in the core may have an impact on local thermal-hydraulic and core physics conditions including the local peaking factor.

INFORMATION NEEDED

Please provide a discussion of how the three-dimensional effects, including spatial xenon redistribution over time, are taken into account in analyzing asymmetric CEA drops for DCD Section 15.4.3. Please include a discussion of any uncertainties that are incorporated into the maximum radial peak distortion factor.

As appropriate, the applicant should update the DCD and referenced technical reports.

Response

The nuclear steam supply system response is simulated using the CESEC-III code and the DNBR is calculated using the CETOP code. The time dependent core average power, average heat flux, coolant temperature, RCS pressure, and coolant flow rate during the transients are calculated using CESEC-III code. Even though the CESEC-III code has a point kinetics solver, these calculated values, which take into consideration the conservative reactivity feedback effects, are conservative. And these calculated parameters are transmitted to the CETOP code to perform the DNBR calculation. The rod drop penalty factor, [ ]^{TS}, is calculated by the three-dimensional ROCS nodal code. This factor is composed of the [ ]^{TS} and the [ ]^{TS}. The [ ]^{TS} can be expressed as the 1-pin peak ratio of post to pre drop condition. All core configurations are required for performing an enormous number of single CEA drop simulations for all possible combinations of initial rod bank insertion, different cycle condition, etc. The top peaked axial power shape is used in the drop analysis. However, the axial power distribution change is neglected during the distortion factor calculation because it is assumed that the only CEA drop from fully withdrawn position to fully inserted position, which would maximize the radial peaking factor, is considered. Additionally, a [ ]^{TS} upper tolerance limit is applied to the distortion factors. In addition to [ ]^{TS}, is considered in the rod drop penalty factor. This factor is to account for the effect of transient xenon during the operator action time (30 minutes). During the xenon redistribution calculation, the magnitude of the initial xenon in the core is adjusted to maximize the power distortion over time.

Impact on DCD

There is no impact on DCD.

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There is no impact on Technical Specifications.

Impact on Technical/Topical/Environmental Report

There is no impact on any Technical, Topical, or Environmental Report.